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DIRECTORY SYSTEMS FOR COMPUTER MAIL IN INTERNETWORKING ENVIRONM--ETC(U)
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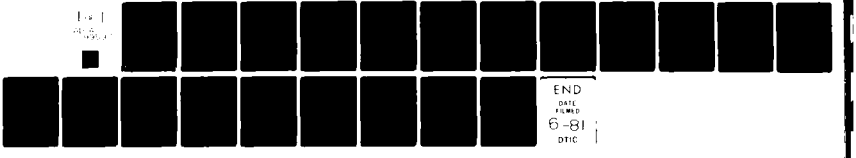

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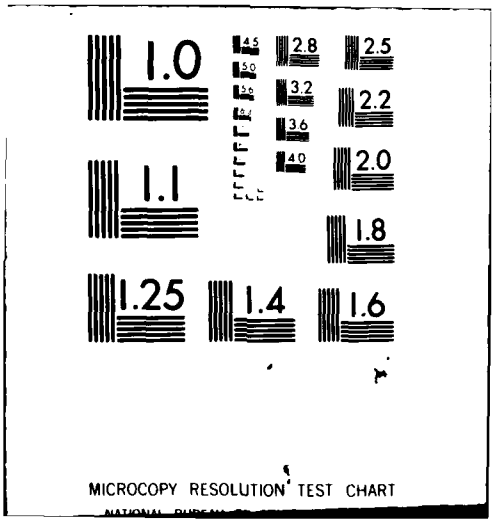
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DIRECTORY SYSTEMS FOR COMPUTER MAIL IN INTERNETWORKING ENVIRONMENTS*

by

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20. Abstract continued

These issues include:

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b. How to control access to the data.
c. How to process identification queries.
d. How to ensure integrity and security of information.
e. How to update the directory system.

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b. How to control access to the data,
c. How to process identification queries,
d. How to ensure integrity and security of information, and
e. How to update the directory system.

1. INTRODUCTION

With the merging of techniques for the communication, storage and retrieval of information in office environments, there is a large market for computer-based message systems. Many systems already exist and many more are expected to be in operation in the future (11). However, today's message systems differ from each other in many ways (2). Thus, the future computer mail environment will be heterogeneous, with a large number of users, many organizations, countries and systems involved. For messages to be delivered, the system-level address of the recipients of the messages must be obtained. This aspect of computer mail system design, the provision of on-line identification services,

requires a directory system to maintain the users' system addresses. Even though directory systems (also named identification database systems) are essential for the effective operation of computer mail systems, especially when large user communities and system interworking are involved, very few studies have been undertaken on the subject (5), (6), (7). In this paper we present design considerations of directory systems for computer mail in internetworking environments.

Section 2 specifies a general model for computer mail systems in which addressing and delivery services are transparent to the users. This model specifies the elements and operation of computer mail systems. The rest of the paper specifies the directory system that maintains the information necessary for that form of system operation. Section 3 describes the organization of the directory system, specifies its functions and delimits the services needed for its operation. Section 4 specifies the structuring of information in the directory system. Section 5 describes the issues associated with the management of the information and the distributed control of the directory system. Section 6 summarizes the main concepts introduced in this paper and points out areas in need of future research.

2. A FUNCTIONAL MODEL FOR COMPUTER MAIL SYSTEMS

2.1. Components

We model a computer mail system by partitioning the system into functional components, each dedicated to a specific set of computer mail functions. There are three different types of functional entities in the proposed model (6): MAILBOX, MAILER, and GATEWAY MAILER.

MAILBOX (MBX) is the entity responsible for the processing, storage and retrieval of user messages. A mailbox serves as the interface between its message system user and delivery services. This component consists of:

a. Message processing modules to compose, edit, retrieve and archive user messages.

b. Communications software to transfer user messages to and from the entity dedicated to message delivery (the local mailer).

c. User files where user messages are permanently stored and (optionally) a personal directory with users' system mailbox addresses is maintained.

d. The message workspace where undelivered messages and messages being composed are maintained.

MAILER (MLR) is the component process responsible for the delivery of messages to and from a specific set of mailboxes and the identification of the system mailbox addresses of the recipients of the messages. The mailer is formed by:

a. Communication software modules dedicated to the communications of the mailer with its local mailboxes and other mailers.

b. The message buffer where messages to and from local mailboxes are temporarily stored.

c. The mailer directory database which maintains addressing information and time-stamped records of message deliveries.

A mailing network is formed by the union of logically connected mailers and corresponds to a public or private message system. Thus, mailing networks (and their corresponding mailers) could be managed and owned by one or more organizations.

GATEWAY MAILER (GMR) is the entity responsible for internetwork communication. Each mailing network has associated with it a gateway mailer, which represents half of the gateway between a given mailing network and any other mailing network. The gateway mailer is formed by modules similar to those of the mailer described above.

A computer mail system consists of a set of interconnected mailing networks. Each mailing network has its own standards to process, deliver and structure user messages. Consequently, a computer mail system is a collection of heterogeneous mailing networks which communicate with each other by means of internetwork protocols via the gateway mailers.

2.2. System Operation

In a computer mail system the sender of a message must enter some meaningful information about the recipient so that the system can identify the recipient and deliver the message. In today's message systems the sender of a message has to enter the formal address (e.g., NIC IDENT code (1), home street address, mail stop) of the recipient in terms of the addressing standards of the system. This may work well for the case of a small system with a homogeneous set of addressing standards. But in an internet environment it would not be feasible for the message system users to handle system addresses of all the various

mailing networks involved because of the differences in addressing formats and standards between mailing networks. On the other hand, it would be very difficult to fix general addressing standards that could be effectively used for internet message delivery and at the same time be feasible enough to be used by humans. Either the flexibility allowed to the users for address specification would be very restricted, or the delivery procedure would be very complex and the users would have to specify too many fields in the addresses. Because of this, in our model delivery and addressing are functions transparent to message system users. The sender of a message should not be concerned with the recipient's system mailbox address or how the message is delivered. To provide such services, a user oriented naming standard is needed to name the recipients of the message in a form as flexible as a postal address for example, and be independent of the addressing standards internal to each mailing network. The system must assist the sender in identifying the system mailbox address from the user-oriented description entered by the sender and then deliver the message according with the address obtained.

We define a user-level naming format called the NOLS address (6), (7), which consists of four major fields that contain information about the recipient of the message, as is shown in Table 1. When the sender of a message enters his message, he also enters a NOLS address with what he knows about the recipient's name and/or title, organization, geographical location and (perhaps) message system.

A NEXUS is an end-to-end virtual connection established between the sender's and the recipient's mailboxes (6). A NEXUS relies on internetwork connections between gateway mailers and intranetwork connections between mailers and their local gateway mailers. A NEXUS address is the specification of a NEXUS in the system. It is specified at the internetwork level as is shown in Table 1. The internetwork address is mapped into intranetwork addresses that follow standards particular to each mailing network, as is shown in Table 1.

Message delivery is carried out in two phases: The NEXUS establishment phase and the message delivery phase. During the NEXUS establishment phase, the system maps the NOLS address (user oriented standard) into a NEXUS address (system oriented standard) and establishes the end-to-end virtual connection. The message delivery phase consists of the dispatch of the message through the NEXUS.

To map NOLS addresses into NEXUS addresses (and those into intranetwork addresses), the system mailbox addresses of message system users must be maintained somewhere in the system.

Table 1. Naming and Addressing Formats

FORMAT TYPE	COMPONENTS
NOLS address (naming)	<N field> <O field> <L field> <S field> N-field -- Contains information about the recipient(s) of the message, such as his name and/or title. O-field -- Contains information about the organization(s), group(s) or system server(s). L-field -- Contains information about the geographical location of the organization(s) or group(s) referred in the O-field. S-field -- Contains information about the System which offers the computer mail services to the recipient(s).
NEXUS (address internet addressing)	([sender's system mailbox address]) , ([recipient's system mailbox address])
network mailbox address	Any format defined in the mailing network.
system mailbox address	<internet address of mailing network> <network mailbox address>

In an internet environment it would not be feasible or desirable to maintain all such addresses in the database of each mailer or even a centralized entity. The information is, by its very nature, distributed and must be organized in such a way that each organization can maintain its own information according to its own needs. Users of the system should be given a simple and integrated view of the information distributed in the system. In our model each mailer maintains only the mailbox addresses of the users served by that mailer, together with a set of mailer addressses (pointers) that the mailer associates with user locations and/or organizations. The NOLS address entered by a sender constitutes a query to the system for identifying the correct system mailbox address. As is shown in Figure 1, the procedure followed to resolve such a query is a store-and-forward process in which the NOLS address is forwarded among mailers and gateway mailers according to the network (inter-network) pointers they maintain. When a mailer (gateway mailer) receives a query, it examines the fields of the NOLS address and based on a search of its directory database, it decides whether to forward the query or to reply with a positive or negative acknowledgement. Once the sender's mailer obtains a positive acknowledgement, the NEXUS between sender's and recipient's mailboxes is created and the message can be delivered (Fig. 1). Various gateway mailers and/or mailers may have to be queried when a NOLS address lacks certain key information, such as name of organization and/or location.

3. DIRECTORY SYSTEM ORGANIZATION AND FUNCTIONS

3.1. Need for a Distributed Organization

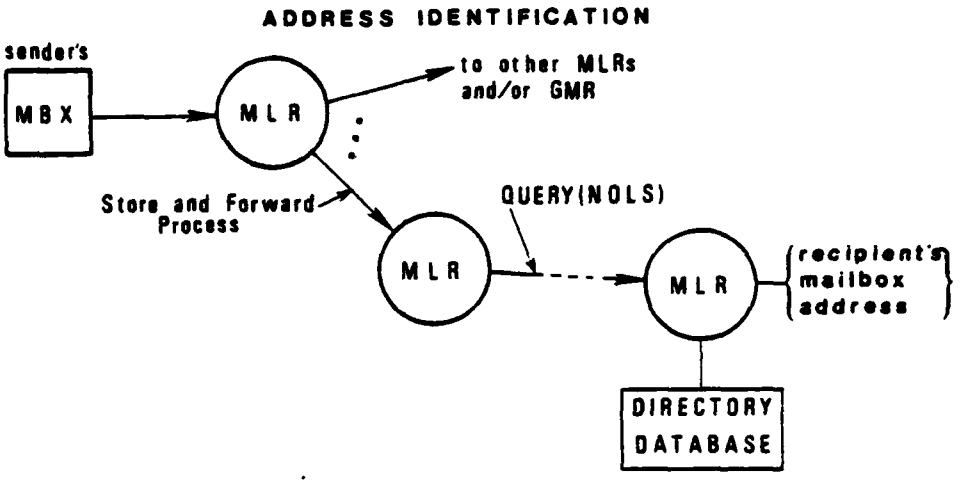
The future environment of computer mail systems will be such that:

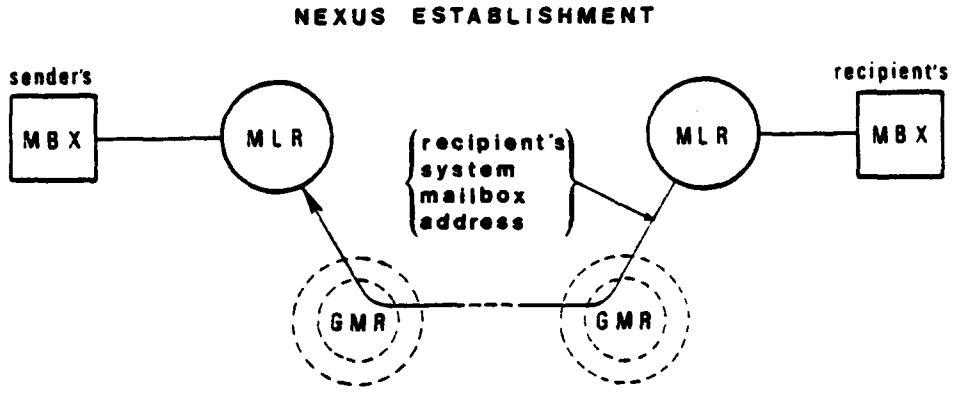
a. Many message systems (public or private) will exist on national and international bases, each with its own addressing standards;

b. Message system users (individuals and organizations) will belong to one or more message systems;

c. There will be many identification databases maintained by organizations containing the information that the organizations need or can afford to maintain;

d. Message systems and private companies will offer public information services. and there will be many differences among the services offered.





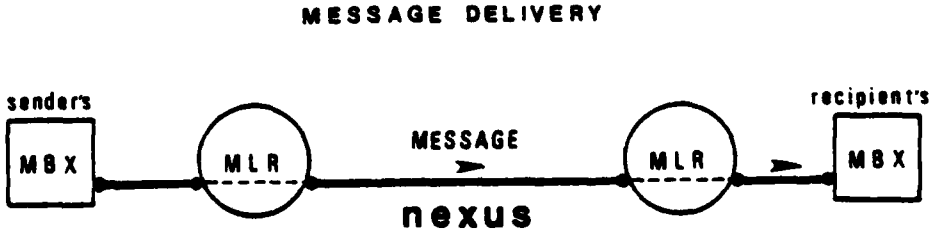


Fig. 1. System Operation

Under such circumstances, the question is not whether the directory system of a computer mail system should be distributed or not, but how to effectively organize the various components of a federation of many heterogeneous database systems to ensure that:

a. An integrated view of the information is presented to the users.

b. Each organization is free to maintain its own information according to its own needs.

c. The computer mail system can provide efficient identification services to all its message system users despite the differences among the various databases.

The directory system is a special-purpose distributed database system aimed at the maintenance of system-level addresses. According to our model, the directory system is formed by the personal directories of mailboxes, the directory databases of mailers and gateway mailers, and software modules to manage such a distributed database.

3.2 Organization of the Directory System Databases

As shown in Figure 2, we organize the databases of the directory system in four levels: the user level, the local level, the network level and the internet level. The local level of the directory system is formed by the union of local directories. Each mailer maintains a local directory with complete identification information about the users served by that mailer only. Such a directory specifies who the message system user is, where he is and (perhaps) what he does (5). The structure and management of the local directory of a mailer is independent of the rest of the system. A local directory corresponds to the identification database of an organization, a branch of an organization, or a regional computer mail server.

The network level of the directory system is formed by the network directories, each of which can be centralized in a single mailer or distributed among the various mailers of a mailing network (Fig. 2). This database is a directory of organizational directories (i.e., the local directories) that allows the mailers to find out where in the network the information about an organization (or one of its branches) is located. That is, the network directory contains mailer addresses (pointers) associated with the organizations served by the mailing network. When a NOLS address referring to a remote organization is received by a mailer, it consults the network directory to find out where to forward the query. This level of the directory system is

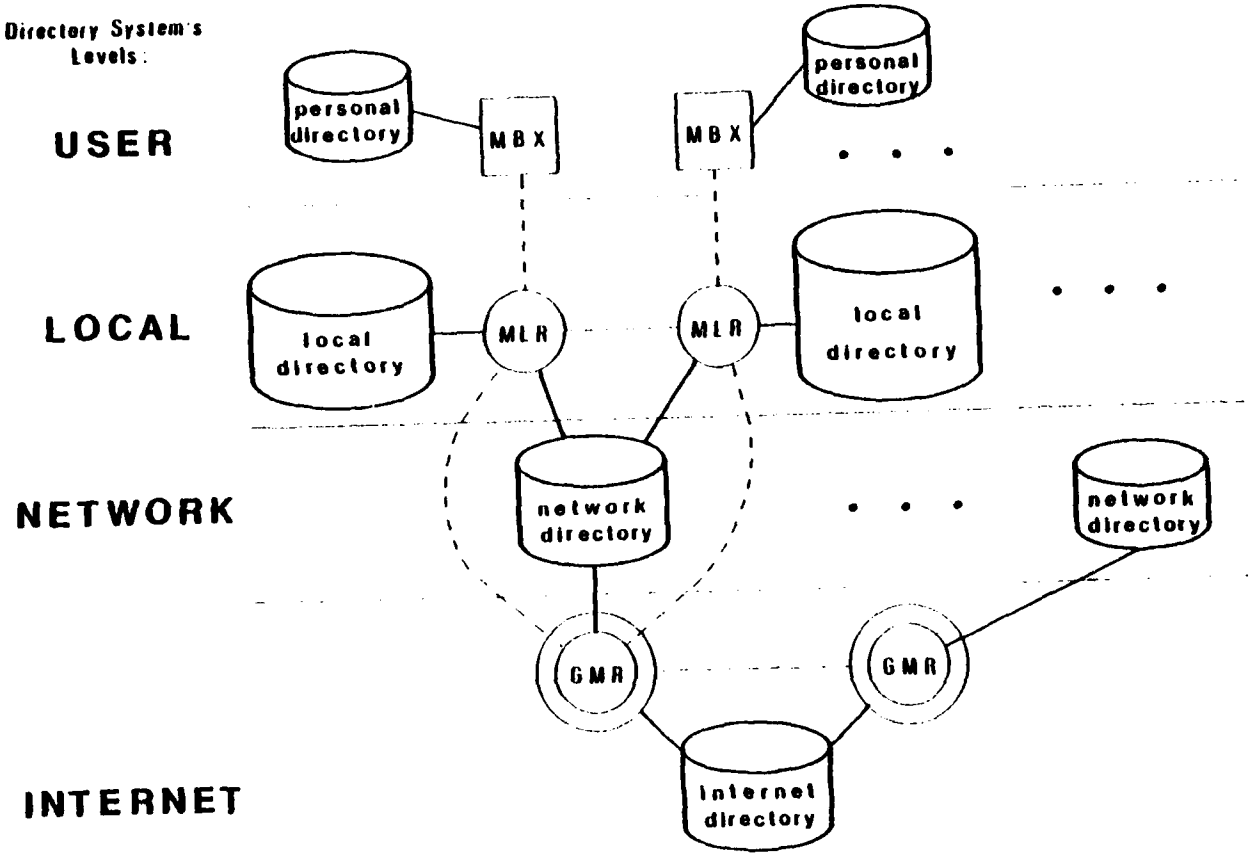


Fig. 2. Organization of Directory System's Databases

concerned with the integration of distributed organizational information into a network-wide database. In the future, this "directory of directories" facility will be implemented by computer mail services, the organizations with their own networks and third parties (e.g., large information companies) (11).

The internet level of the directory system is formed by an internetwork directory, which can be either centralized in a single gateway mailer or distributed among the various gateway mailers of the computer mail system. This database plays the same role as a network directory, but at the internet level. That is, it is a directory of network directories that allows the gateway mailers to find out where in the system the information about a mailing network is located. When a gateway mailer receives a NOLS address referring to an organization or a geographical region (i.e., a country) remote to its mailing network, it consults the internetwork directory and forwards the query correspondingly. This internetwork database should be implemented as a joint effort of the parties desiring to interconnect with each other.

The user level of the directory system is formed by the personal directories that are (optionally) maintained in the mailboxes. A personal directory contains system mailbox addresses (plus some extra information) of those recipients commonly addressed by the sender. Each user manages the information contained in his personal directory in a form completely independent of the rest of the system.

3.3. Directory System Software Modules

The software necessary to manage the databases of the directory system is a distributed database management system that handles both the communication between the various computer mail processes (mailboxes, mailers and gateway mailers) and the database management operations at each site. The functions of these software packages can be partitioned into layers following the ISO's Reference Model (8). As is shown in Figure 3, the software that controls the interaction between the various database systems corresponds to the session, presentation and management (application) layers. The existence of transport services (4) is needed to support the establishment of logical connections between process in different host computers and communication networks. The management layer supports the functions particular to the management of the directory system's databases, integrating them into a single entity. These functions are:

a. To provide the message system users with a unified, global view of the information stored in the directory system's databases, and to allow them to enter system-wide queries;

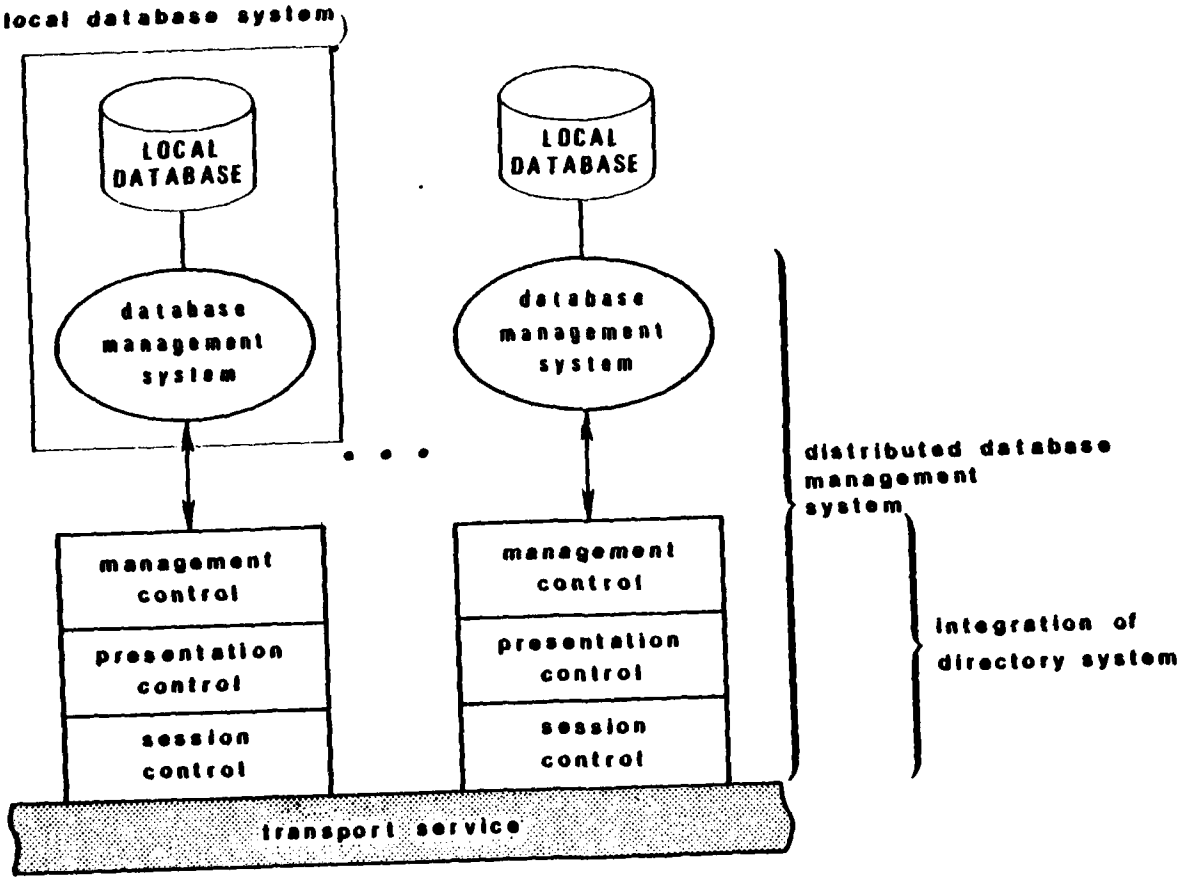


Fig. 3. Integration of Databases in the Directory System

b. To permit the exchange of information between heterogeneous databases according to a standard structure of information;

c. To ensure consistency and security of the information maintained in the directory system;

d. To resolve system-wide queries; and

e. To provide error recovery.

The session and presentation layers support the establishment of reliable end-to-end virtual connections between computer mail processes and the exchange of information in standard formats. In this paper we are only concerned with the management layer of the software of mailboxes, mailers and gateway mailers. The existence of both presentation-level services (8) and the local database management systems will be assumed.

4. STRUCTURE AND DISTRIBUTION OF INFORMATION

A system-wide data model is needed to describe the (logical) structure of the information maintained in the directory system and to structure the message system users' queries. In our model a system-wide user schema is defined that gives the users a unified view of the logical structure of the information, independent of the distribution of information and the structure of the system. The user schema is the External Schema (3) of the directory system. Based on this schema a set of rules can be defined to structure NOLS addresses. Each mailing network has a network schema that standardizes the logical structure of the information distributed in the network. Such a schema is the Conceptual Schema (3) of the network and is used by mailers to plan the processing of the queries. In the same form, an internet schema is defined at the internet level. Each local directory in a mailer has its own (logical and physical) structure. Individual mailers translate the information communicated in NOLS addresses into formats locally defined in their local directories. A mapping procedure is necessary at the gateway mailers of those mailing networks whose network schemas differ from the internet schema.

The Entity-Relationship data model (2) is a good candidate to represent the internet and network schemas of the directory system because the model is rich in semantic information about the data and can be easily translated into different data models. Since the exact structure of NOLS addresses is yet to be defined,

Table 1 only gives the type of information that could be effectively used on a system-wide basis.

In our model information is distributed by schema instances. A schema instance consists of the information whose structure is defined by a schema, and is therefore semantically complete. The semantics of the information (i.e., types of entities, relationships and attributes) is defined by the organizations at the local level, and by the Directory System Administrator (DSA) at the network and internet levels. Therefore, at the local level the local directory of each mailer maintains semantically complete information about the local users. At the network level a network directory maintains semantically self-contained information about the organizations in the mailing network. Either one, various, or all the mailers of the network have a copy of the network directory. The same applies to the internet level, where the gateway mailers of the system have a copy of the internet directory.

As it has been pointed out in (9), distribution of information by schema instances reduces communication costs. In addition, the hierarchical distribution of information by schema instances of the proposed model reduces the complexity of the communication protocols. On the one hand all detailed information about individuals is maintained with no (network-level) redundancy. On the other hand the information that has to be maintained at network and internetwork levels refers only to organizations and mailing networks and not to individuals, and changes in such information are infrequent.

5. DIRECTORY SYSTEM CONTROL

The procedures used for the control of the directory system rely on the hierarchical organization of the system and the distribution of information by schema instances. The control of the directory system is carried out in three levels: local, network and internetwork.

5.1. Query Processing

In our model a mailer can resolve queries that refer to its local users but not queries that refer to remote users. These queries must be forwarded to remote mailers. The processing of a query depends on the distribution of the network and internet directories. Throughout this discussion we will assume the correct operation of mailers and gateway mailers and the consistency of information in the directory system.

When a sender enters a query to his mailer that refers to remote users, the sender's mailer must determine where to forward the query. If it has a copy of the network directory, the mailer determines which mailers maintain the information about users in organizations and/or geographical locations that fit the data in the sender's NOLS address. Accordingly, the sender's mailer forwards the query to all those mailers. Each such a mailer locally processes the query (based on its local directory) and as a result it either obtains the recipient's mailbox address or a list of "similar names" (containing the information about a set of users that fit the sender's description), or the queried mailer cannot associate any local user to the NOLS address. If the sender's mailer does not have a copy of the network directory, it simply forwards the query to a mailer that has a copy and such a mailer continues the processing of the query. The same query processing procedures apply at the internet level depending on the distribution of the internet directory.

Note that the exact form in which a query is processed may not be known by the sender's mailer and various mailers (gateway mailers) may have to be queried if the NOLS address lacks key information such as location. Each of the queried mailers (gateway mailers) replies to the sender's mailer (gateway mailer). Once the sender's mailer obtains the replies from all the queried processes, either a NEXUS has been established (Fig. 1) or the queries have failed to identify the system mailbox address(es) necessary for message delivery.

3.2. Directory Updating and Error Recovery

Because of the organization of the directory system and the nature of the information maintained at the network and internet levels, the updating procedures are very simple. At the local level, no database synchronization is required between mailers since each mailer independently maintains its local directory. Local locking is only required to ensure the consistency of the local information. At the network level, mutual consistency of the various copies of the network directory can be obtained with no need for synchronization among mailers. Each mailer sets aside a workspace (private storage) for every transaction where the information accessed by the (read or write) transaction is copied. Therefore, various readers and one writer can concurrently access any entity in the network directory. There are practical forms to implement this scheme (10), (15). Using local locking (10) each mailer ensures the local consistency of information. The DSA issues (time-stamped) updates to all the mailers of the mailing network when a change occurs at the network level. Each mailer processes the update in an asynchronous form with respect to the other mailers. If a mailer receives a query (NOLS address) that refers to an organization whose system address has just changed and the mailer has

not yet updated such data in its copy of the network directory, the mailer will erroneously forward the query to the organization's former mailer. The same type of error would occur if a mailer crashes and its copy of the network directory is out of date when the mailer comes back to operation. To recover from network-level identification errors, a forwarding mechanism is used that works as follows:

Each command (query, update or message) contains the following control information:

- A command identifier
- The next distination of the command
- A forwarding list that identifies the mailers (gateway mailers) that have handled the command.
- A time-stamp (14)
- The identification of sender and receiver

When a query is received by a mailer it determines whether or not the NOLS address refers to an organization that has changed its system-level address. If that is the case, the query is forwarded to the appropriate mailer and an update is sent back to the mailer that issued the query to update its database. The update contains time-stamped information elements and the information stored in the mailer's database also has the time-stamp of the last update. When the mailer that issued the query gets the updating command, it checks the time-stamps of the information stored and transmitted and determines if its database is out of date, in which case it is updated.

This forwarding mechanism is loop-free because of the forwarding record included in every command. Any mailer with out-of-date information is detected by means of the use of time-stamps. Therefore, error recovery from process failures or differences caused by updates from the DSA is supported by our model. Repeated updates can also be detected by the time-stamps in information.

The same procedures described above apply to the internet level. Error recovery procedures require that the information stored in local directories be never destroyed, since it is locally maintained by mailers. If a copy of the network (internet) directory is destroyed, a new copy can be transmitted to the crashed mailer (gateway mailer) without penalty because it is a small portion of the entire database.

6. CONCLUSIONS

In this paper we have presented a general framework for the design of address directory systems for computer mail and we have proposed various techniques aimed at internet milieus and large computer mail systems. The organization of the directory system we propose is such that each organization can independently maintain its own local identification database. The individual organization databases are then integrated into a system-wide distributed database, presenting the users of the system a unified view of the information. The form in which senders describe the recipients of their messages is independent of the structure of the computer mail system and its delivery and addressing procedures. Such user-oriented descriptions (NOLS addresses) constitute queries to the system and not as physical addresses as in the postal service. The system maps those descriptions into system-level addresses (NEXUS addresses) needed for message delivery in a form transparent to the users. Various studies related to the design of computer mail protocols exist in the literature (13), but the role of directory systems for system address identification have been overlooked. International standards are needed to specify a common logical structure of identification information and thus permit the open interworking of heterogeneous identification databases.

Inside small networks, provisions could be made to overcome the necessity of a two-phase delivery procedure such as the one we propose. For example, users could be asked to enter very specific NOLS addresses and use them as the formal system-level addresses for delivery. Message delivery could be allowed to public bulletin boards maintained in mailers. In this form, messages could have a chance of delivery even if the recipient's mailbox address was not obtained.

The simplicity of the control procedures of the directory system we propose rely on the hierarchical organization of information. If redundancy is introduced at the local level (i.e., more than one local directory contains information about a given user), synchronization among the various mailers is required to deal with local-level updates and as a consequence, the control procedures become much more complex.

7. ACKNOWLEDGEMENTS

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